08:36:21 OCA PAD INITIATION - PROJECT HEADER INFORMATION 12/03/92

Active

Project #: E-25-X58
Cost share #:
Rev #: 0
Center # : 10/24-6-R7677-0A0
Center shr #:
OCA file #:
Work type : RES
Contract#: 6B117
Mod #:
Document : PO
Prime #: 2582
Contract entity: GTRC

Subprojects ? : N
CFDA:
Main project #:
PE #:

Project unit: MECH ENGR Unit code: 02.010.126
Project director(s):
BAIR S S III MECH ENGR (404)894-3273

Sponsor/division names: BALL AEROSPACE SYSTEMS DIV /
Sponsor/division codes: 201 / 004

Award period: 921014 to 930110 (performance) 930110 (reports)

Sponsor amount	New this change	Total to date
Contract value	12,000.00	12,000.00
Funded	12,000.00	12,000.00
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: HIGH-PRESSURE VISCOSITY MEASUREMENTS

PROJECT ADMINISTRATION DATA

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Security class (U,C,S,TS) : U
ONR resident rep. is ACO (Y/N): N
Defense priority rating : DO-A7
N/A supplemental sheet
Equipment title vests with: Sponsor GIT
NONE PROPOSED OR ANTICIPATED.
Administrative comments -
INITIATION OF PROJECT E-25-X58 (FIXED PRICE).

5/8469 2

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 01/28/93

Project No. E-25-X58 | Center No. 10/24-6-R7677-0A0

Project Director BAIR S S III | School/Lab MECH ENGR

Sponsor BALL AEROSPACE SYSTEMS DIV/

Contract/Grant No. 6B117 | Contract Entity GTRC

Prime Contract No. 2582

Title HIGH-PRESSURE VISCOSITY MEASUREMENTS

Effective Completion Date 930110 (Performance) 930110 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	Y	
Final Report of Inventions and/or Subcontracts	Y	
Government Property Inventory & Related Certificate	N	
Classified Material Certificate	N	
Release and Assignment	Y	
Other	N	

CommentsEFFECTIVE DATE 10-14-92. CONTRACT VALUE $12,000.

Subproject Under Main Project No.

Continues Project No.

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
GTRC	Y
Project File	Y
Other HARRY VANN-FMD	Y
FRED CAIN-OOD	Y

NOTE: Final Patent Questionnaire sent to PDPI.

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HIGH-PRESSURE-VISCOSITY MEASUREMENTS

a final report to

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Aerospace Systems Group
P.O. Box 1062
Boulder, Colorado 80306-1062

by Scott Bair
Tribology and Rheology Laboratory
George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology

December, 1992

INTRODUCTION

The Georgia Tech Tribology and Rheology Lab has undertaken the measurement of viscosity of synthetic saturated hydrocarbon oils to high pressure for various temperatures. Two test samples were provided by Ball Aerospace. A total of eight pressure-viscosity isotherms were obtained at temperatures of -25, 0, 40, and 100°C for each oil. This final report details the dynamic viscosity at various pressures from atmospheric pressure to 765 MPa or to the viscosity limit of the viscometer (10^6 m Pa·s). The initial pressure-viscosity coefficient and the reciprocal asymptotic isoviscous pressure are reported. In addition, parameters for a Free Volume Model have been calculated for the two samples.

VISCOMETER

The pressure-viscosity results reported here were obtained with a falling body viscometer which applies a maximum shear stress of approximately 20 Pa. The reported viscosities may be assumed to be the limiting low shear viscosity owing to the very low shear stress. The viscosity measurement technique is discussed in Ref. [1].

RESULTS

The measured viscosities are listed in Table I and plotted in Figure 1. Each entry is the average of at least two falls - more at the lowest pressures. For 40 and 100°C some entries are the average of results using two different sinkers (see Figure 1). Measurements were routine.

Two types of pressure-viscosity coefficient are tabulated (see Table I). They are the initial pressure viscosity coefficient, α_o, and the reciprocal asymptotic isoviscous pressure, α^*, defined below at constant temperature.

$$\alpha_o = \frac{1}{\mu}\frac{\partial\mu}{\partial p}\Big|_{p=o} = \frac{\partial \ln\mu}{\partial p}\Big|_{p=o}$$

$$\alpha* = \left[\int_o^\infty \frac{\mu(o)}{\mu(p)}\,dp\right]^{-1}$$

where p is pressure and μ is viscosity. The coefficient which best represents the film forming capability is α*.

Sufficient data were obtained to regress the parameters for the Free Volume Model [2] shown below. These parameters are listed in Table II. The glass transition is regarded as an isoviscous process with viscosity, μ_g, at the glass transition temperature, T_g. Since the glass transitions of these samples were not measured, μ_g was arbitrarily taken to be 10^7 Pa s as suggested by Yasutomi [2]. Now, T_g represents a reference temperature rather than the true glass transition temperature. The relative free volume expansivity, F, can be empirically related to the liquid expansivity [2].

$$\mu = \mu_g \cdot \exp\left[\frac{-2.3\, C_1\,(T-T_g)\,F}{C_2 + (T-T_g)\,F}\right]$$

where

$$T_g = T_{go} + A_1 \ln(1 + A_2 p)$$

$$F = 1 - B_1 \ln(1 + B_2 p)$$

and A_1, A_2, B_1, B_2, C_1, and C_2 and T_{go} are parameters to be evaluated. The above relations may be used to find viscosity for conditions not measured for this report. However, our regression was not successful at capturing the inflection in the pressure-viscosity curve at 0°C.

REFERENCES

[1] Bair, S., "An Experimental Verification of the Significance of the Reciprocal Asymptotic Isoviscous Pressure", ASLE Tribology Trans., accepted for publication (1992).

[2] Yasutomi, S., Bair, S., and Winer, W., "An Application of a Free Volume Model to Lubricant Rheology", Trans. ASME Journal of Tribology, 106, 2 (1984).

TABLE I. PRESSURE-VISCOSITY RESULTS

mPa·s

$$\alpha_o = \frac{1}{\mu}\frac{\partial\mu}{\partial p}\Big|_{p=o} \qquad \alpha* = \left[\int_o^\infty \frac{\mu(p=o)}{\mu(p)}\,dp\right]^{-1}$$

	37964				37999			
P/GPa	**-25°C**	**0°C**	**40°C**	**100°C**	**-25°C**	**0°C**	**40°C**	**100°C**
0	4,870	580	58.4	7.51	8,320	943	84.6	10.5
.069	32,600	2,810	225	24.7	62,500	4,301	318	29.1
.146	128,000	13,180	638	53.9	252,000	16,200	894	67.4
.223	502,000	44,200	1,856	111.4		54,500	2,170	158.5
.301		227,000	4,350	220		240,000	5,240	234
.456			21,200	699			24,200	697
.610			84,700	2,004			90,900	1,872
.765			404,000	5,210				4,990
α*/GPa	25.5	22.1	17.4	13.7	27.0	20.7	16.8	12.4
α_o/GPa	32.2	24.2	22.3	20.6	34.5	24.2	21.9	16.6

TABLE II. FREE VOLUME PARAMETERS

SAMPLE	μ_g/Pa·s	T_{go}/°C	A_1/°C	A_2/GPa^{-1}	B_1	B_2/GPa^{-1}	C_1	C_2/°C
37964	10^7	-100.2	97.41	1.303	0.1739	15.97	12.374	71.17
37999	10^7	-92.14	88.17	1.381	0.1632	17.21	12.101	66.37

where

$$\mu = \mu_g \cdot \exp\left(\frac{-2.3\, C_1\, (T-T_g)\, F}{C_2 + (T-T_g)\, F}\right)$$

$$T_g = T_{go} + A_1 \ln(1 + A_2 p)$$
$$F = 1 - B_1 \ln(1 + B_2 p)$$

Figure 1. Pressure-viscosity curves.